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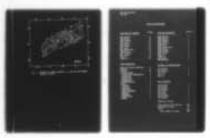

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THE STABILITY OF THE SHALLOW SOUND CHANNEL IN THE EASTERN NORTH ATLANTIC

by

ROBERT I. TAIT

15 NOVEMBER 1977

NORTH ATLANTIC TREATY ORGANIZATION

VIALE SAN BARTOLOMEO 400
I – 19026 – LA SPEZIA, ITALY

Published by

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SACLANTCEN MEMORANDUM SM-102

NORTH ATLANTIC TREATY ORGANIZATION
SACLANT ASW Research Centre
Viale San Bartolomeo 400
I 19026 — La Spezia, Italy

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9 Memorandum rept.,

11 15 Nov 1977

12 13p.

14 SACLANTCEN-SM-102

This memorandum has been prepared within the SACLANTCEN Applied Oceanography Group.

R. Tait
Group Leader

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THE STABILITY OF THE SHALLOW SOUND CHANNEL IN THE EASTERN NORTH ATLANTIC

by

Robert I. Tait

ABSTRACT

West of Gibraltar the SOFAR sound channel is split by the outflow of water through the Strait. Measurements confirm that the geographical extent of the shallower of the two subchannels is related to the extent of the higher-salinity outflow near 1000 m depth. Other data indicate that there is only a modest degree of variability in the parameters of the shallow sound channel over relatively large horizontal scales. The magnitude and stability of the shallow sound channel, which is found to extend across the western approaches of Europe, recommends it for further study by acousticians and for use by oceanographers in tracking current floats.

INTRODUCTION

In the eastern North Atlantic, the outflow of high salinity water from the Mediterranean exerts a considerable influence on the sound-speed profiles over a large area. This intrusive water mass, whose core is to be found at depths between 1000 and 1200 m, has a relatively high temperature (∿ 10°C), salinity (∿ 36‰), and sound speed (∿ 1515 m/s) compared with the North Atlantic water masses. It has two effects on the sound-speed profile:

a. Because the core of the Mediterranean outflow lies near the depth of the Atlantic SOFAR axis it splits the sound channel into two subchannels: an upper one around 600 to 700 m and a deeper one around 1700 to 1800. Characteristically the sound-speed minima defining the two axes are separated by a high-speed layer due to the Mediterranean core. Hence the intensity of the upper sound channel, defined here as the difference in sound speed between the shallow axis minimum and the Mediterranean maximum, is directly related to the intensity of the Mediterranean outflow.

b. As a consequence of the splitting of the SOFAR axis, the deep sound channel is depressed to a depth that increases from about 1400 to 1800 m as we approach the Iberian coast and it has a corresponding anomalously high sound speed: 1496 to 1502 m/s [1].

The existence of a shallow sound channel as a permanent feature of the eastern North Atlantic has important implications in both active and passive sonar systems. It also presents the possibility of using high-powered Swallow floats in conjunction with shore-based receiving equipment to study the current field. The purpose of this memorandum is to discuss the upper sound channel in the light of some recently acquired Nansen cast data and in particular to present some unpublished STD data from the University of Liverpool, U.K., on the variability of the channel.

1 THE UPPER SOUND CHANNEL

Figure 1 shows typical salinity, temperature, and sound-speed profiles for the eastern North Atlantic at a range of some 300 n.mi from Gibraltar. An extension of the sound-speed profile to include the deep sound channel is given in Fig. 2. It is clear from Fig. 1 that the sound-speed maximum at 1200 m, which forms the lower boundary of the upper channel, is mainly determined by the high salinity of the Mediterranean water and therefore, to a first approximation, the salinity maximum can be used to determine the spatial extent of the upper channel. A geographical plot *[2]* of the isohalines at a depth of 1000 m is given in Fig. 3, which presents the classical picture of the high-salinity core hugging the Iberian coast and diffusing westward. One would expect the upper sound channel to show a similar distribution in intensity.

The recent acquisition by the SACLANTCEN data base of Nansen Cast data for the eastern North Atlantic has enabled a direct appraisal of the horizontal extent of the upper sound channel to be made. The results of this analysis are given in Fig. 4, which shows isopleths of the channel intensity, ΔV, based on mean annual values for 2^0 squares for all available stations over the last 30 years. The similarity to Fig. 3 is apparent; the high values in the Bay of Biscay and the extension as far as north as Ireland should be noted. No data was available for west of 20^0W. However, if we arbitrarily define the useful limits of the upper channel as being delineated by the 1 m/s ΔV contour, then it is clear that the zone extends from the Canaries to Ireland and westward as far as about 22^0W.

2 THE STABILITY OF THE UPPER SOUND CHANNEL

In spite of the long period over which the data had accumulated, many stations did not go deep enough to encompass the salinity maximum, and the coverage in some areas was sparse, particularly in the winter months. Attempts to contour ΔV by seasons were unsuccessful, partly through lack of data but mainly because the seasonal variability is in fact small. It is well known that the maximum outflow from the Mediterranean occurs during late winter & early spring, but the salinity maximum is largely determined by localized mixing processes in the Strait of Gibraltar rather than by changes in the source value, which remains relatively constant.

Hence variability in the salinity maximum occurs mainly at relatively short time scales. Figure 4 can therefore be considered as representing the mean situation independent of time. This lack of seasonal variability was also found in data from two Liverpool University cruises in the research ship SHACKLETON (UK) in August 1970 and March 1973, which showed no significant difference between the mean channel parameters for the same area. However, the results of the 1973 observations throw some light on the spatial variability, which will now be discussed.

The area in question is indicated on Fig. 4 as the zone marked "Detail" lying some 180 miles southwest of Cape St. Vincent. Sound-speed measurements were made with a Plessey velocity meter, fitted to a Bisset Berman 9006 STD, over a network of 34 stations at a nominal 20 n.mi spacing. The area is shown in detail in Fig. 5. The numbers indicate the ΔV values at each station position, which have been contoured as in Fig. 4. The mean value of ΔV is 7.87 m/s, with a standard deviation of 0.87 m/s, and is somewhat higher than one would deduce from Fig. 4. However, this is to be expected, because Nansen Cast data, having a much lower depth resolution than the STD, would tend to underestimate ΔV ; (Fig. 4 thus probably presents a somewhat pessimistic view of the channel intensity).

The fact that meaningful contours can be drawn in Fig. 5 indicates that the temporal variability is small and that the spatial variability occurs on a relatively large scale, of the order of 30 to 90 n.mi. Corresponding changes of about 10% in the thickness of the channel were also found. The spatial changes observed are considered to originate in temporal changes in the mixing processes in the Strait of Gibraltar. Tidal activity, one of the main sources of periodic mixing, could account for the smaller (30 n.mi) scale fluctuations while large scales are more likely to arise from changes in the weather conditions in the vicinity of the Strait.

It is probable that the spatial variability observed is not untypical of the general situation over a wide area: one could therefore assign a similar variability i.e. about 10% of the ΔV value to the contours of Fig. 4.

CONCLUSION

The existence of a dual sound channel in the eastern North Atlantic has been recognized for some time, but apart from the work of Piip in 1968 [1] and the more recent mention by Northrop and Colborne in 1974 [2] it appears to have received little attention. The exploitation of this permanent oceanographic feature, which covers the whole of the western approaches to Europe, is a task which surely merits further study.

The dimensions of the upper channel are such as to permit the propagation of ducted rays over vertical angles from 3 to 6° with respect to the axis. From a purely oceanographic point of view, this amount of energy within a duct of around 1000 m in thickness is sufficient to give acceptable values of transmission loss ($\sim$ 100 dB) for the tracking of low-frequency Swallow floats, at ranges up to 1000 km [3].

The data presented here indicate only a modest degree of variability in the channel parameters over relatively large horizontal scales. Such effects, if characteristic, should have only a small influence (< 3 dB) on the transmission loss.

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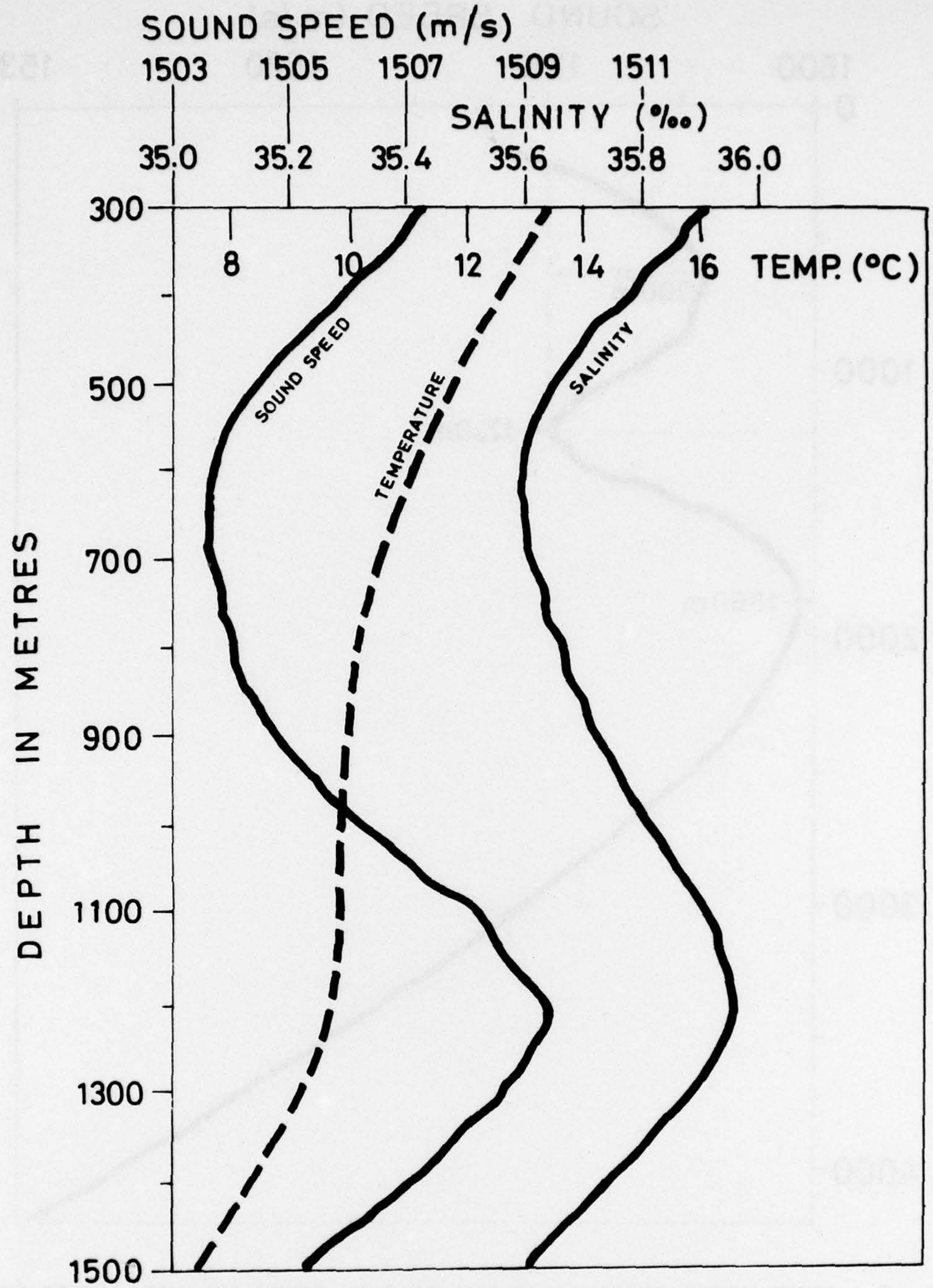

FIG. 1 TYPICAL SOUND SPEED, TEMPERATURE, AND SALINITY PROFILES FOR THE EASTERN NORTH ATLANTIC 300 n.mi FROM GIBRALTAR

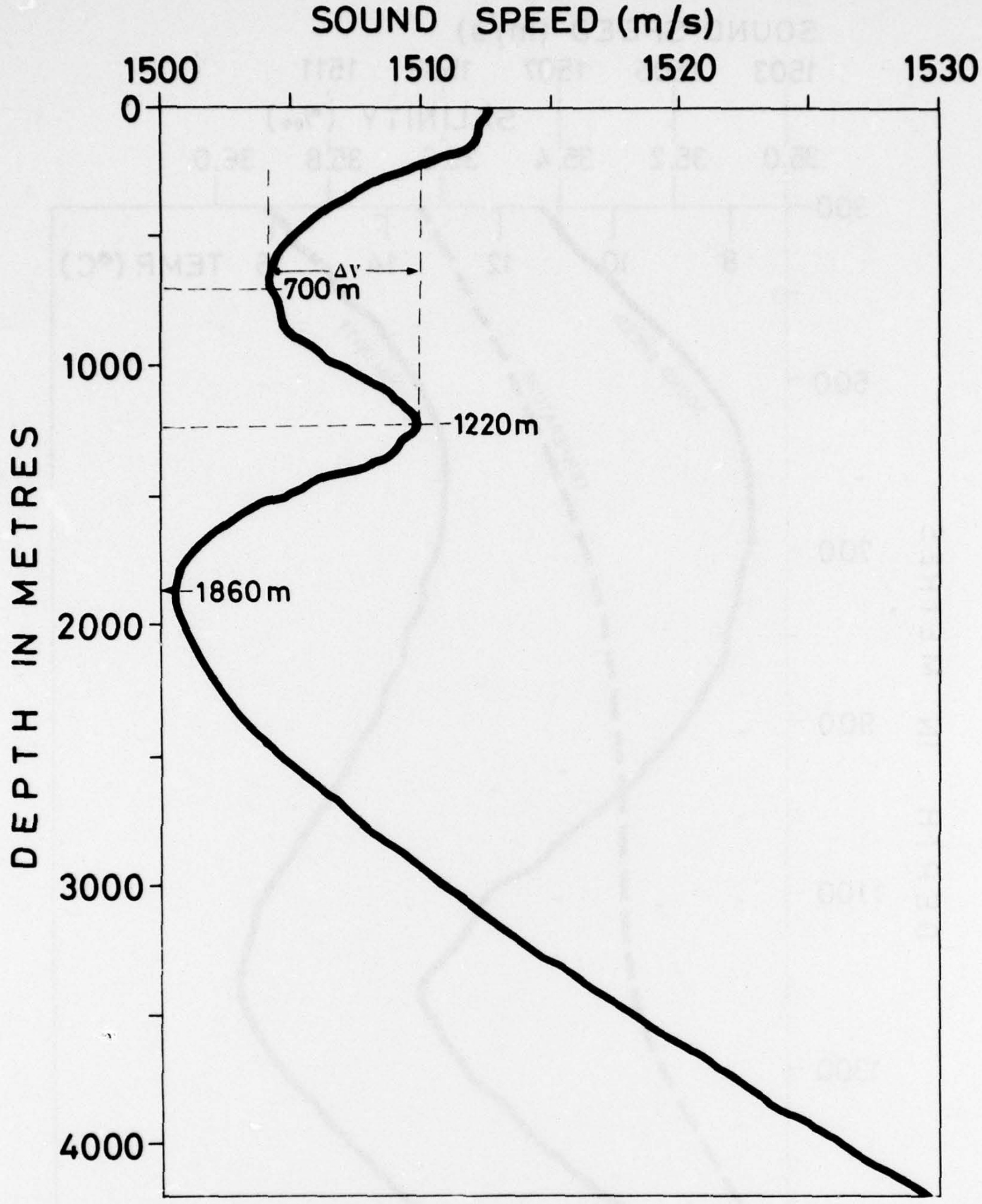

FIG. 2 SOUND SPEED PROFILE FOR THE EASTERN NORTH ATLANTIC, WEST OF GIBRALTAR, SHOWING THE SPLITTING OF THE SOUND CHANNEL

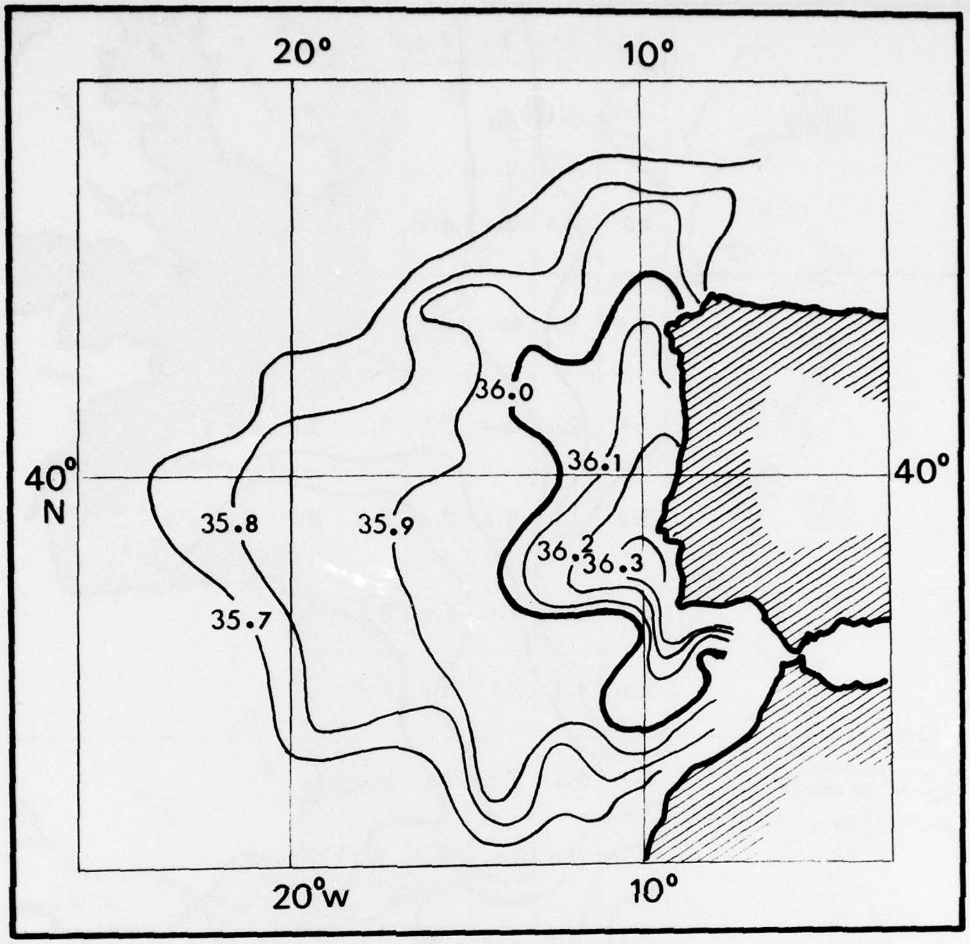

FIG. 3 ISOHALINES AT 1000 m DEPTH

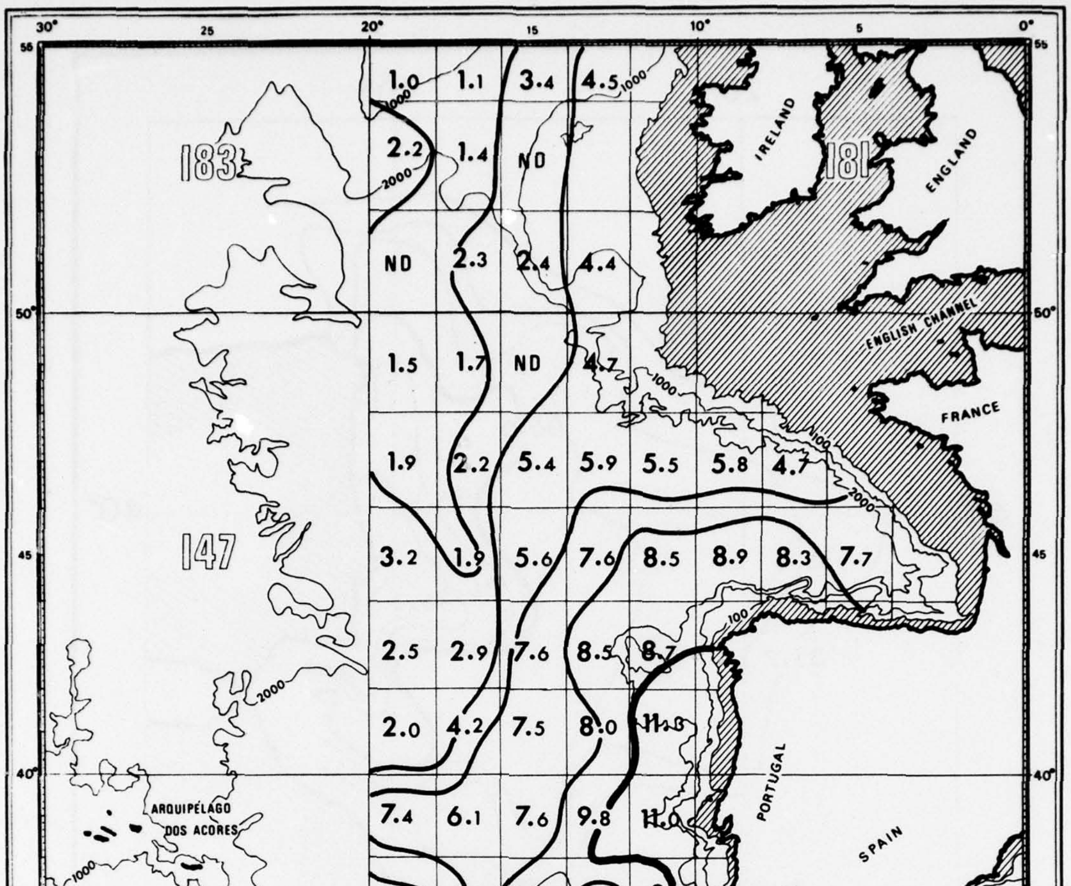

FIG. 4 CONTOURS OF CHANNEL INTENSITY, ΔV (see Fig. 5 for area marked DETAIL)

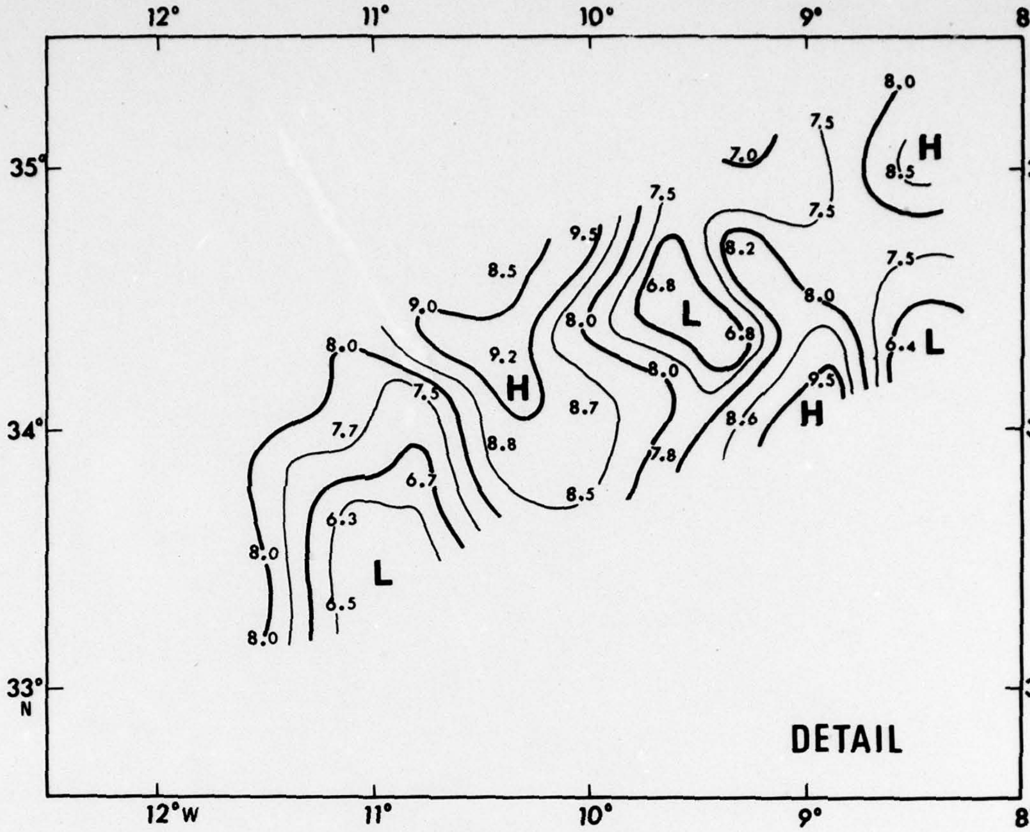

FIG. 5 CONTOURS OF CHANNEL INTENSITY, ΔV, FOR THE AREA MARKED "DETAIL" IN FIG. 4

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